Comprehensive Capital Analysis and Review:
Industry Practices in Model Validation

High performance. Delivered.
Since the inception of the US Comprehensive Capital Analysis and Review (CCAR) exercise, we have seen financial institutions make significant investments in quantifying and managing risk. In every submission cycle we have witnessed the introduction of enhanced levels of compliance standards from regulators and to counter this, enhanced techniques of risk quantification from Bank Holding Companies (BHCs). A multitude of models created to this end have given rise to an independent and voluminous body of work concerning the validation of these models.

Validation of stress testing models poses a unique challenge. We have observed the Federal Reserve System (the Fed) identify weaknesses in the way many participants validate their models. Ideally, deficiencies not identified at the conceptualization and modeling stage should be spotted and corrected by effective validation. This would help protect the BHC from reputational risk of stress test failure as well as the expenditure of millions of dollars on corrective measures.

In an industry where there are multiple and unprecedented pressures on competitiveness, regulatory compliance that is well integrated with risk and business strategy would in our view become a differentiator that would separate the future leaders from the rest.

Expectations and Challenges

The expectations for model validation as laid out by the Fed touch upon all stages of the model development lifecycle. The role of effective validation, performed by an independent entity includes:

- Evaluation of conceptual soundness to support methodology and approach;
- Outcomes analysis to gauge how model predictions differ from actual outcomes; and
- On-going monitoring to support robust implementation and use over time.

Our focus in this document is on the evaluation of conceptual soundness and analysis of outcomes.

The typical challenges BHCs face in the validation of CCAR models include: scarcity of credible and applicable data for modeling; heavy and undocumented use of "expert" judgment/overlays; and limited historical instances of stress to effectively back-test the robustness of model performance under stress. These challenges are compounded many times over by the stringent submission time frames set by regulators.

Also, given the evolving regulatory expectations, a key challenge BHCs face today is not validation itself, rather it is gauging regulatory expectations and responding to them. We have observed instances in which a BHC’s progress in addressing Matters Requiring Attention (MRA) on prior submissions was considered unsatisfactory by regulators. Common instances in which BHCs are caught off guard include: the level of validation performed not matching the Fed's expectations; model performance thresholds considered satisfactory in previous submissions being considered inadequate in subsequent submissions; and a lack of empirical evidence supporting the use of overlays.
CCAR Model Validation Framework

In our experience, the key to effective validation is twofold, first to provide an independent view on model validation and second to adhere to a transparent, repeatable and conceptually sound framework. Developing such a framework requires comprehensive coverage of both qualitative and quantitative aspects of model validation, as depicted in Figure 1 below.

This document will apply the below framework to help describe the quantitative and qualitative model validation approaches for the two inputs to capital projections: Losses and Pre-provision net revenue (PPNR). It should be noted that due to the nature of components modeled and inputs leveraged, PPNR model validation typically relies more on qualitative approaches than on quantitative approaches. The opposite is typically the case for Loss model validation.

Figure 1. Accenture’s Model Validation Framework

- Gather and review model specific information:
  - Business purpose and model usage
  - Technical documentation
  - Development of data reports
  - Model theory/logic and codes
  - Operating procedures
  - Key assumptions and limitations
  - Model selection and process
- Interview model owners to understand objectives and assumptions
- Assess the appropriateness of the selected data sample for model development, for stress testing the inclusion of at least one business cycle
- Evaluate the portfolio segmentation scheme in accordance with FR Y-14A reports submitted to Fed
- Data reconciliation and validity checks
- Assess treatment of missing values and outliers
- Assess suitability of using proxy data where applicable
- Assess conceptual soundness of the model and relevance to published research and/or sound industry practices
- Test assumptions and assess appropriateness of the chosen modeling approach for intended business purposes
- Consider reviewing alternative methodologies and designs
- Evaluate the variable selection process
- Assess model development evidence
- Conduct back-testing to evaluate model performance
- Perform model sensitivity analysis
- Conduct benchmarking and comparison to challenger models
- Assess the impact and reasonableness of management overlays
- Review model output reports for completeness and accuracy
- Assess the reasonableness of scenario forecasts
- Review model risk management policies and procedures
- Review performance monitoring plan including:
  - Frequency of monitoring performance metrics
  - Evaluate data quality controls in place
  - Track model outcomes with realized macroeconomic variables
- For vendor models, review contingency plan in case the vendor model is no longer available
- Conduct reviews of validation findings with model risk governance and model owners

Source: Accenture, June 2016
Quantitative Validation of CCAR Models

1. Loss Models

Loss is typically estimated through models subject to the availability of data. In our view, the following represent common approaches used in credit Loss modeling for retail and wholesale asset classes:

**Economic loss-based approach**

Losses are estimated as a function of three components: probability of default (PD), loss given default (LGD), and exposure at default (EAD). These models can be developed at a loan level (survival analysis, fractional logit regression) or segment level (transition state models).

**Accounting-based approach**

Losses are estimated using accounting-based techniques such as roll-rate models, rating transition models, vintage models and charge-off models.

Quantitative validation of Loss models developed through any of the listed approaches involves back-testing, sensitivity analysis and application of key statistical tests to gauge overall model robustness. As listed in Figure 2 below, depending on the underlying modeling approach, the most appropriate metrics should be selected covering relevant validation areas. These metrics may be evaluated in-sample, out-of-sample or across multiple sub-samples.

Based on industry benchmarks and bank’s model validation standards, thresholds are established for each metric to help identify models on a Red-Amber-Green (RAG) Status scale for gauging model performance.

**Figure 2. Key Quantitative Metrics in Loss Model Validation**

<table>
<thead>
<tr>
<th>Validation Areas</th>
<th>Description</th>
<th>Key Metrics</th>
<th>Vintage Models</th>
<th>Transition State Models</th>
<th>Probit/Logit-based Expected Loss Models</th>
<th>Roll Rate-based Models</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>Comparison of actual to model predictions. For example, in vintage models comparison is across age of maturity.</td>
<td>Mean Absolute Percentage Error (MAPE)</td>
<td>○</td>
<td>○</td>
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<td></td>
<td></td>
<td>Mean Absolute Error (MAE)</td>
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<td></td>
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<td>Root Mean Square Error (RMSE)</td>
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<tr>
<td></td>
<td></td>
<td>Cumulative Percentage Error (CPE)</td>
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<td>○</td>
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<tr>
<td></td>
<td></td>
<td>McFadden Pseudo R-squared</td>
<td>○</td>
<td>○</td>
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<tr>
<td><strong>Stability</strong></td>
<td>Analysis of shift in population characteristics from the time of model development to any reference time period.</td>
<td>Population Stability Index (PSI)</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td></td>
<td></td>
<td>Character Stability Index (CSI)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td><strong>Sensitivity</strong></td>
<td>Capturing the sensitivity of models to macroeconomic factors by performing factor prioritization and factor mapping.</td>
<td>Sensitivity Ratio</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td><strong>Model Discrimination</strong></td>
<td>Validation of the statistical measure of models’ ability to discriminate risk.</td>
<td>Kolmogorov-Smirnov</td>
<td>○</td>
<td>○</td>
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<td></td>
<td></td>
<td>C-statistic</td>
<td>○</td>
<td>○</td>
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<td></td>
<td></td>
<td>Gini Coefficient</td>
<td>○</td>
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<td></td>
<td></td>
<td>Concordance</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td><strong>Alternate Vintages</strong></td>
<td>Comparison of behavior of Loss in different vintage models.</td>
<td>MAPE</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
</tbody>
</table>

Source: Accenture, June 2016
2. PPNR Models

PPNR has historically been a measure of focus for the finance department when conducting strategic exercises. Compared to Loss modeling, PPNR modeling methodology is still evolving. With consistent improvements in credit quality post the recent crisis and Loss estimation attaining a level of maturity, regulators are focusing on PPNR modeling with increased interest. The focus of validation varies, depending upon the nuance of the metric being validated and the estimation technique in use. For modeling techniques common with Loss estimation, the metrics listed for Loss model validation in Figure 2 will also apply to PPNR models.

Outlined below are common industry practices for estimating PPNR and focus areas for validating each of the PPNR sub-components such as net interest income (NII), non-interest revenue (NIR) and non-interest expenses (NIE).

Validation of NII sub-components

Net interest income is one of the primary components of PPNR. It is computed by forecasting balances, including originations and pricing rates.

Balances

Typical estimation approaches include quantile regression, regime switching regression and time series modeling. Balances can correspond to loans and deposits. While secured loans are typically estimated and validated using quantitative modeling techniques, non-secured loans are validated using a mix of qualitative and quantitative techniques for each loan’s individual components.

Origination

Typical estimation techniques include a combination of qualitative approaches such as assumption-based projections and quantitative approaches such as simple linear regression models. More recently, we have seen the use of more complex estimation methods and increased regulatory focus on new modeling techniques and their underlying assumptions (e.g., stationarity of variables in time series ARIMAX modeling).

Pricing

Typical estimation approaches include modeling customer rates using linear regression, log normal distribution or gamma distribution simulation. The interest rate is an important component of the model and the primary validation target. Validation of customer rate models in particular relies on the use of dummy test-models to confirm whether pricing movements are in line with interest rates.

Validation of NIR components

NIR primarily comprises fee income and has been typically estimated using linear and quantile regression techniques; however, newer and more complex dynamic coefficient techniques such as state space or regime switching models are now being deployed. The primary focus of quantitative validation is on the dimensions of accuracy and stability of models.

Validation of NIE components

NIE primarily consists of fixed expenses with personnel-related expenses typically being the largest part of this component. NIE estimates are predominantly obtained using empirical calculations or through simple linear or time series regression techniques at advanced banks. Since there is heavy reliance on business inputs, estimation and validation is driven more by qualitative aspects wherein senior management plays an important role. This is further explained in the next section which focuses on qualitative aspects of validation.
Qualitative Validation of CCAR Models

In the last two years, regulators have increased their focus on the qualitative aspects of validation. However, managing these expectations can be overwhelming, even for some of the most seasoned financial institutions. As shown in Figure 3, Accenture has developed a comprehensive framework that addresses regulatory expectations by focusing on four key areas for the qualitative validation of CCAR models.

The key in our view, is applying the right validation approach to the individual entity in each case and adequately addressing all material exposures. Where gaps exist, they should be flagged and aggressively managed as part of an effective validation process. Based on our experience with global financial institutions, we have identified some emerging themes related to regulators’ expectations regarding validation of qualitative components of Loss and PPNR models.

1. Loss Models

We have observed that BHCs are being scrutinized to confirm that they capture losses from all asset classes and operations and that they are not making any favorable assumptions not representative of their business model or market conditions. Key themes in Loss model validation include:

**Conceptual soundness**

Discussions with the lines of business should be well documented. Business intuition should be evident and the relationship between Loss and its drivers should be backed by economic theory in addition to statistical soundness.

**Outcome analysis**

Outcome analysis should be performed to validate that scenarios are directionally correct. This should include a downturn test to help assess if severely adverse and adverse projections point in the right direction and are sufficiently conservative. If there are important changes in business models such as business expansion, these should be adequately reflected in the model outputs.

2. PPNR Models

For PPNR, the qualitative aspect of validation typically precedes the quantitative aspect. Of particular interest are the selection processes and the granularity of final models. BHCs should demonstrate a reasonable process for the selection of final models backed by an effective challenger process and documentation. The level of granularity of models should take into account factors such as asset class, business judgment and geographic footprint commensurate with the maturity of PPNR data available at the BHC. Key themes in PPNR include:

**Integration**

Balance and origination forecasts should be in line with Loss models. Some of the large BHCs are using a single modeling approach for PPNR and Loss.

**Conservatism**

The margins of conservatism should be factored into the validation effort; in particular, the supervisory expectation is to make conservative adjustments to model outputs where assumptions or data limitations might lead to a non-conservative bias.

**Conceptual Soundness**

Model captures impact of macroeconomic environment to portfolio performance and business dynamics.

Documentation supports judgmental assumptions, where possible using empirical analysis.

**Data and Methodology**

Historical data selection is credible, applicable and sufficient.

Usage of internal vs. proxy data reflects portfolio attributes.

Model methodology is sound and appropriate.

**Model Design**

Consideration given to portfolio characteristics.

Satisfactory evaluation of segmentation schema.

Model variables adequately capture material risk drivers and are justified by business rationale.

**Model Output**

Model produces sufficient stress levels under different scenarios.

Scenario forecasts generated are directionally sound.

Benchmarking validates consistency of macroeconomic environment and model outputs.

Source: Accenture, June 2016
Validation of business assumptions

NIR and NIE, in particular, rely on business assumptions that need validation, such as growth rates feeding into a BHC’s loan origination projections. Assumptions that heavily rely on judgment without support from any empirical analysis or documented and intuitive rationales are being questioned by regulators.

Outcome analysis

There are two areas of focus for validation here. The first is benchmarking the outputs generated from treasury with those from the finance function. We believe that this is becoming increasingly important in the eyes of regulators, especially in their assessment of a bank’s enterprise-wide risk evaluation mechanism. The second is the relationship and responsiveness of pricing models to changes in the macroeconomic environment.

Integration

In PPNR estimation, integration involves aligning balance forecasts with Loss estimates. Our experience shows that some of the largest BHCs are using an integrated modeling approach for PPNR and Loss and wherever a divergence in assumptions exists, it is being questioned.

Internal controls

Given large executive involvement in developing PPNR estimates, BHCs are required to demonstrate robustness of controls and thus provide an appropriate level of data reconciliation, checks and procedures. It is also important in our view for the BHCs to have an approval system in place through which model equations and variable drivers are signed-off on by the respective business units.
Vendor Model Validation

Use of vendor-supplied models has gained importance for a variety of reasons. However, firms using these models should weigh the typical lack of complete transparency against the benefits they present. Figure 4 depicts the key challenges associated with the use of vendor models.

The regulatory expectation is that banks will apply the same rigor in validating vendor models as they do for their in-house developed models. Where the proprietary nature of these models limits full-fledged validation, BHCs should perform robust outcomes analysis including sensitivity and benchmarking. They should monitor models periodically and maintain their conceptual soundness, supported by adequate documentation on model customization, developmental evidence, and applicability of the vendor solution to the bank’s portfolio. The key to effective validation of vendor models is to address each aspect associated with applicability to specific BHCs as depicted in Figure 5.

By leveraging a framework similar to the one described and demanding necessary levers for conducting stress tests, BHCs can favorably navigate vendor model validation challenges and benefit from their many advantages.

![Figure 4. Challenges Associated with the Use of Vendor Models](image)

**Figure 4. Challenges Associated with the Use of Vendor Models**

| Risk of Using Wrong Model | • Inapplicability of vendor model  |
|                         | • Incorrect model specifications |
|                         | • Insufficient details on model limitations |
| Risk of Using Complex Model | • Models based on complex approaches with insufficient explanation of methodology and algorithm |
| Model Quality | • Inapplicability of input data or lack of confidence in the quality of data, definitions and treatment |
| Inconsistent Modeling Standards | • Violation of portfolio specific industry standards for modeling purposes |
| Inconsistent Model Usage | • Incoherent documentation of models due to confidentiality claims |

**Model Quality**

- Inapplicability of input data or lack of confidence in the quality of data, definitions and treatment
- Inconsistent subjective inputs

**Inconsistent Modeling Standards**

- Violation of portfolio specific industry standards for modeling purposes
- Incoherent documentation of models due to confidentiality claims

**Discrepancy in Model Usage**

- Black-box models, distorting model usage
- Calibration errors and model calculation errors

Source: Accenture, June 2016

![Figure 5. Focus of Vendor Model Validation](image)

**Figure 5. Focus of Vendor Model Validation**

| Model Applicability | • Model and underlying data representative of bank’s portfolio characteristics and modeling philosophy |
|                     | • Appropriateness of model specifications and customizations |
|                     | • Transparency of vendor model approach |
| Model Integrity | • Developmental evidence indicating model soundness |
|                    | • Soundness of methodology backed by academic research and industry acceptance |
|                    | • Conformity to industry standards for traffic lights |
| Justification of Customization | • Justification for customization of model methodology and assumptions |
|                     | • Supporting analysis justifying customizations made to the vendor model |
| Validation of Components | • Data access, documentation, completeness and portfolio representation |
|                    | • Review of assumptions and replicability of model estimates by validators |
| Documentation | • Documentation of pertinent model components, assumptions and design specifications |
|                   | • Documentation of model limitations and mitigation plan |
| Outcome Analysis | • Ongoing model monitoring and outcomes analysis of model fit, including aspects such as accuracy, stability, discrimination and sensitivity |

Source: Accenture, June 2016
Conclusion

Given the high stakes associated with financial stability, regulators have established strict standards for stress testing. These compliance standards have become increasingly stringent with the increasing size, scope of operations and systemic importance of BHCs. While the Fed recognizes challenges faced by first-time CCAR participants, the room for error remains small. As the latest results indicate, no amount of capital buffer to satisfy quantitative criteria can make up for what the Fed perceives as fundamental deficiencies in risk measurement and model risk management processes.

There is potential for BHCs to turn the process of surmounting this regulatory hurdle into a source of competitive advantage. BHCs stand to derive strategic benefits from employing the right models and validating them properly. They can also realize cost reductions through greater operational efficiency, reduced model risk and a better understanding of the hidden risks in their various business activities. The pillars of effective model validation—evaluation of conceptual soundness, performing adequate outcome analysis and ongoing model monitoring—can all be structured to help reach the ultimate objective of helping financial institutions develop the appropriate business models for navigating the post-crisis era.
References


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